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The Other Side of Design for Assembly

Whitepaper

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DFA and Beyond…

'Design for Assembly is a process by which products are designed with ease of assembly in mind.' This is how Wikipedia begins the page on Design for Assembly (DFA). DFA recognizes the need to analyze both the part design and the whole product for any assembly problem early in the design process. Companies have been practicing DFA for a long time, mainly as a set of guidelines for designers to follow. Geoff Boothroyd developed a method for estimating the time and cost for assembly, and then proposed a method to minimize the number of parts in a product. Similar methods have been proposed by other researchers, namely, the GE Hitachi method, the Lucas method and several others. All these methods primarily concentrate on reducing the assembly time and cost of a product.

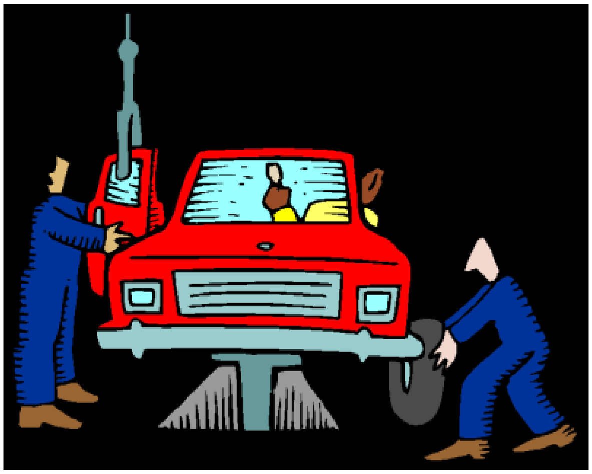


Figure 1: Assembly

However, are these assembly problems the only ones every designer faces on a day-to-day basis?

- Not at all! A designer needs to ensure that his design is complete and good-to-go for functional, performance, manufacturing and assembly requirements of the product. The designer will design the part and use various tools and techniques to check the design on various parameters.

When the part fits into an assembly, things get a little more complex. Assembly level constraints need to be satisfied before the design can move downstream. Even though these issues are best addressed at the design stage, many organizations have chosen to skip them till date because of various problems ranging from non-availability of tools, cost and complexity of existing tools to time required for the manual methods, etc. The same issues are handled downstream using other methods like testing, prototyping, etc.

This whitepaper will go through various assembly level issues, which need to be tackled by various organizations on a regular basis. These issues are not restricted to ease of assembly but also address functional and performance requirements of the product. Traditional DFA methods and tools are skipped in the following sections, since the objective of this paper is to bring forth 'the other side' of DFA.

Clearance Requirements

Clearance between specific components of an assembly is important in many types of products. Examples of clearances to be maintained include - clearance between fan and casing, clearance between capacitor and housing, clearance between two conducting components, connector pin height clearance, etc. Typically, such clearance checks are very common in electromechanical assemblies. The clearance requirements may originate from a variety of sources - electrical, thermal, etc.

A common scenario in the design of electronic assemblies is the back-and-forth between mechanical and electronics departments due to design changes. Typically, PCB design is prepared in 2D and then the complete PCB assembly is brought into the mechanical CAD environment using the IDF format. In most cases, the requirements for the packaging of the product constrain the shape, size, and position of the PCAs (printed circuit assemblies). Based on these constraints, the MCAD designer determines the board outline, size and locations for mounting holes, if required. The mechanical designer places critical components such as connectors, LEDs, etc., since their locations are ascertained by the product packaging itself. Typically, multiple iterations may occur between electronic and mechanical designs before the design is finalized. For components with no direct 3D MCAD models, the MCAD IDF translators create the models as extrusions according to their height.

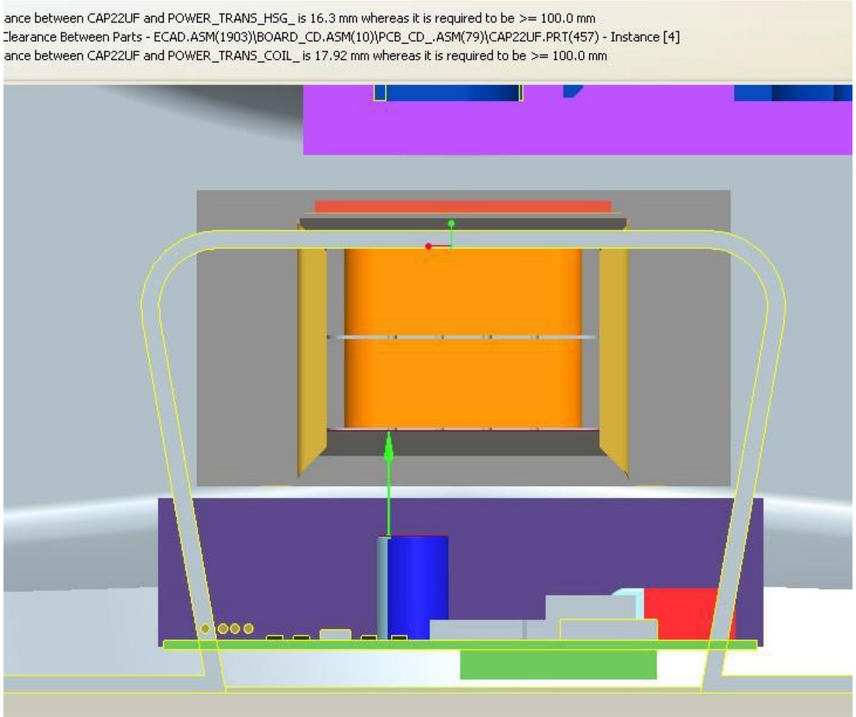


Figure 2: Clearance Analysis in DFMPro

In the three dimensional environment, clearances between various electronic and mechanical components have to be verified with each iteration, prior to shipping the design for manufacturing and assembly. Typical CAD systems provide generic clearance checks, which need to be executed for specified clearance value on the complete assembly or on a specific pair of components. However, clearance requirements are usually more complex and expressed more easily in terms of rules. For example, clearance around capacitors of type A needs to be greater than 'x' mm, whereas clearance around capacitors of type B needs to be greater than 'y' mm. Minimum distance between heat-sinks should be greater than 'z' mm.

For automotive assemblies, rules of the following nature are common: clearance around machined surfaces should be greater than 'a' mm, whereas clearance around casting surfaces should be greater than 'b' mm.

When expressed as separate clearance rules, it is easy to turn on or off these checks, configure them individually and group the results accordingly as depicted in Figure 2.

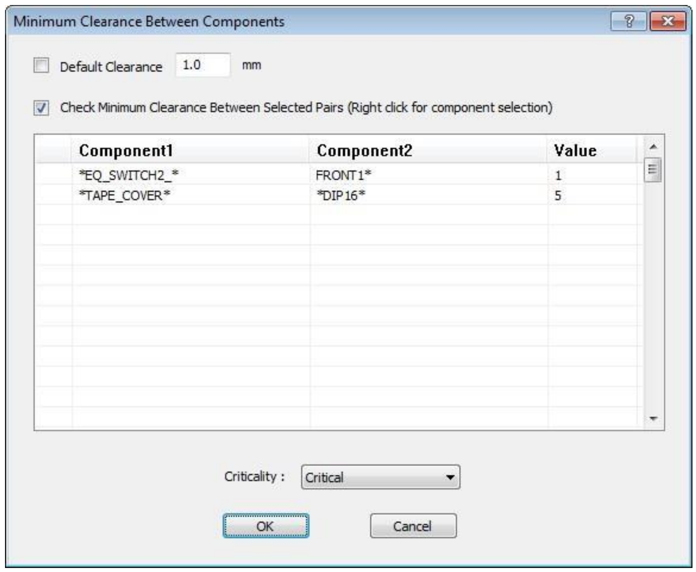


Figure 3: Clearance checks configuration in DFMPro

More detailed clearance requirements arise in various cases depending on the specific application:

- In a given clearance check, certain types of components having different characteristics may have to be excluded.
- Clearance/ mating checks may need to be applied on components of a specific material - this kind of check is important when joining plastics.
- In some cases, clearance needs to be verified between groups of components which may not directly correspond to a sub-assembly in the product. Users must have tools to easily define such groups and perform clearance analysis.
- For mechanical assemblies having different types of components, different clearance values may need to be specified for surfaces created either by machining or by casting.
- Clearance checks must be able to ignore purely mating surfaces, which are created as per functional requirements.

Clearance conditions may be visible or hidden in a designed assembly. Visible clearance requirements might be easier to detect; however, certain clearance conditions hidden in a complex assembly needs additional work like sectioning for detection. Easy-to-use tools with rule based clearance checks simplify this task and increases the productivity of the user to a large extent.

It is easy to gauge the enormity of the clearance analysis task. Executing the CAD based generic clearance checks and then filtering the results based on the specific component will take a significant amount of time for a mid-sized assembly. Now imagine if one has to rerun the check because one dimension of a core component changed!

Interference checks

Interference checks seem trivial and possibly something, which can be generically handled by the CAD system. However, this is not the case always. In some cases, interference results, because of the way modeling is done, does not actually happen during the physical assembly; while in other cases, it is the result of the process of assembly and the manner of representing it in CAD.

In many organizations, fasteners will be modeled just for representation purpose and will not contain the thread information. In other cases, threads will be cosmetic attributes of the fastener and/or of the corresponding hole. Figure 8 shows different fastener representations in CAD. Interference checking tools must be able to ignore such cases, which arise because of the design representation process.

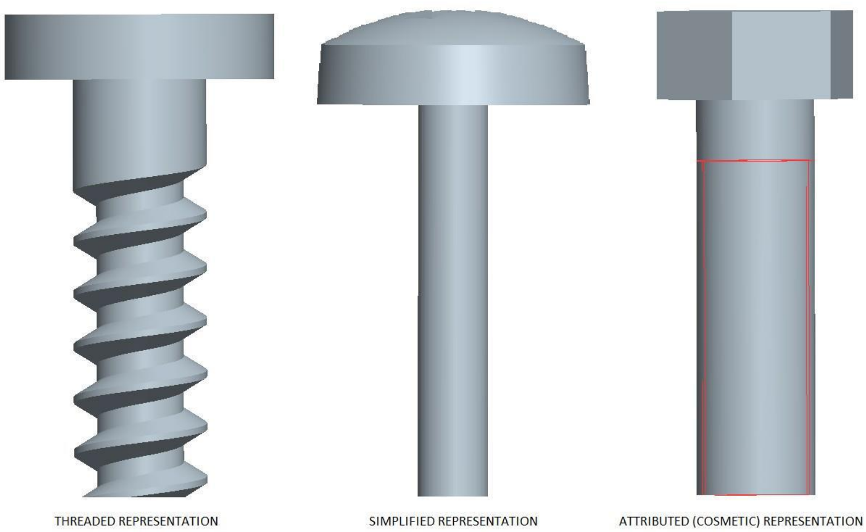
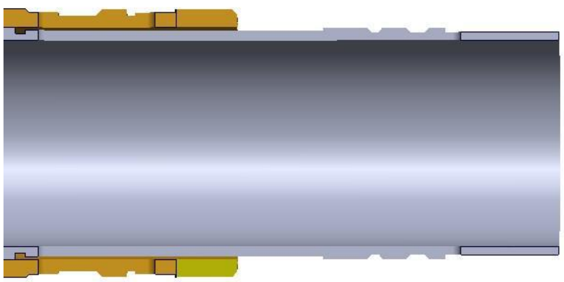


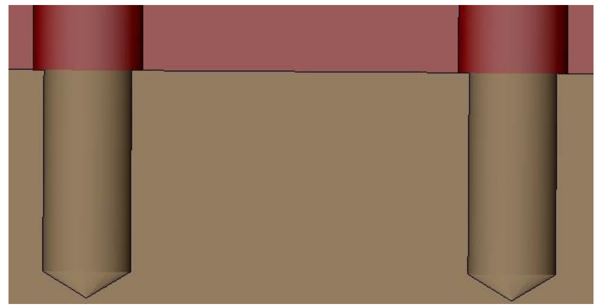
Figure 4: Fastener representations in CAD

Alignment and Angularity Checks

Hole alignment checks help easily determine whether the parts are located as per assembly fastening requirements or they are misaligned. Misaligned holes can damage the threading or the component during assembly, leading to rework and scrap. Similar analysis is useful in case of tube assemblies.



Alignment of tubes



Alignment of holes

Figure 5: Alignment checks in assembly

Fastener Insertion and Checks

Fasteners are typically the most neglected components in product designs; but a fastener costing less than one percent of the final product cost can affect the product quality, thus, impacting the brand of the organization. Traditionally, organizations avoided designing fasteners in 3D because it increased the size of the CAD file considerably. However, with organizations moving towards a Model-Based Enterprise, CAD systems handling file sizes intelligently, and disk space and computing power becoming less and less of a constraint, fasteners in 3D assemblies are now common.

Earlier, with the 3D design not having the fastener geometry, any kind of checks on fastener appropriateness were not possible. With fasteners now being designed in the 3D assembly, design automation and automated checks during design are a reality. Typical requirements related to designing a fastener in assembly are of two kinds - automated fastener insertion, and fastener clearance and projection checks.

- Automated fastener selection and insertion: Automated fastener insertion helps reduce/ eliminate errors in fastener selection depending on the kind of logic built into the selection utility. By building a fastener selection database based on certain design standards and functional requirements, it is possible to automate fastener selection. For machine bolts and nuts, logic can be embedded in the form of rules for appropriate selection of the bolt, nut and spacer/ washer, based on operational and loading conditions and the size of the hole or slot. Similarly, for assemblies involving plastic parts, selection of thread-forming, thread cutting or machine screws based on specific conditions can be accomplished.

- Fastener clearance checks: Ensuring adequate radial and axial clearance for fasteners is important to ensure ease of assembly and desired functional performance. Fastener clearance check is a specific example of generic clearance requirements. It is a difficult task since the clearance is not directly visible in the assembled condition. Moreover, certain portions may possibly be modeled with interference to represent the threaded assembly, so the software must have a facility to ignore interference and threading conditions, while checking radial and axial clearance for the fastener. Figure 6 depicts typical requirements for fastener clearance (A is the radial clearance, whereas B is the axial clearance. The figure on the left shows a nut and bolt assembly while the assembly on the right is of a plastic component using a self-tapping screw.

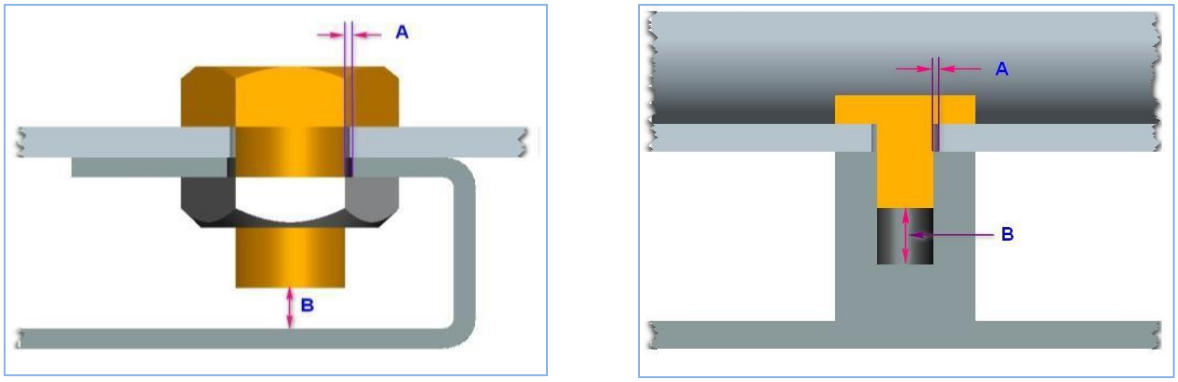


Figure 6: Fastener Clearance

- Fastener projections: In electronic assemblies, thread extensions more than a specific amount are to be avoided. Similarly, bolts or screws, without locking mechanisms, extending less than the specified amount is also not recommended. Ensuring adequate bolt projections is equally necessary to ensure proper assembly and functioning of the bolt. Similar to fastener clearance, a simple check for verifying adequate bolt projection saves a lot of time normally spent in such checks.

Welding Requirements

To ensure easy manufacturing of a welded assembly, certain guidelines are provided. Spacing from weld to part edge, spacing of the weld from holes and distance between consecutive welds (Figure 7) are important parameters to be considered while designing welds. Depending on the type of weld (arc, spot, seam, projection), various guidelines need to be followed to improve weld strength, reduce the cost and minimize distortion.

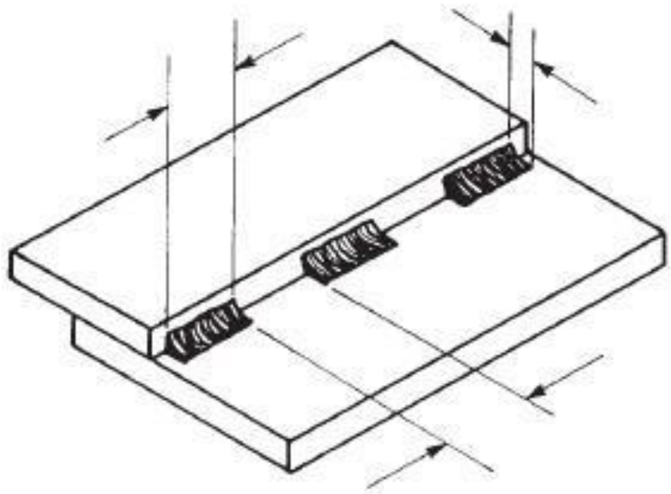


Figure 7: Welding guidelines

Similar to welding, manufacturability and assembly considerations also need to be accounted for in other joining processes like brazing, adhesive bonding, etc. during the design stage. Joining considerations are very important, especially, when joining two dissimilar materials with different thermal and other properties.

Other Assembly Considerations

Designers are also concerned with other assembly restrictions, for example, space constraints for the assembly. The questions to be answered in this area include:

- What is the volume occupied by this component? This volume is not just the material volume, but the space taken up by the component, which would reduce the space available for other components. This figure is less than the typical shrink-wrap volume data, which is provided by CAD systems.
- Is the component easy to assemble? Is there adequate space for maneuvering the component?
- Is there sufficient clearance for inserting tools required for fastening the component to the assembly?
- Is the component accessible for service and maintenance?

Another broad area, which is a research topic on its own, is tolerance stack-up analysis. There is a variety of software in the market ranging from the simplest excel-based tool to the highly advanced simulation-based tools, which addresses this problem. Some organizations have built in-house tools to meet their specific requirements on tolerance analysis.

Archival of Results and Reporting

It is not only necessary to compute the required data and perform the necessary checks, but also provide facilities for archival of results and reporting mechanism delinked from CAD. A 3D interactive report, which has additional annotation capabilities and can be shared outside the CAD environment, facilitates quick and easy collaboration.

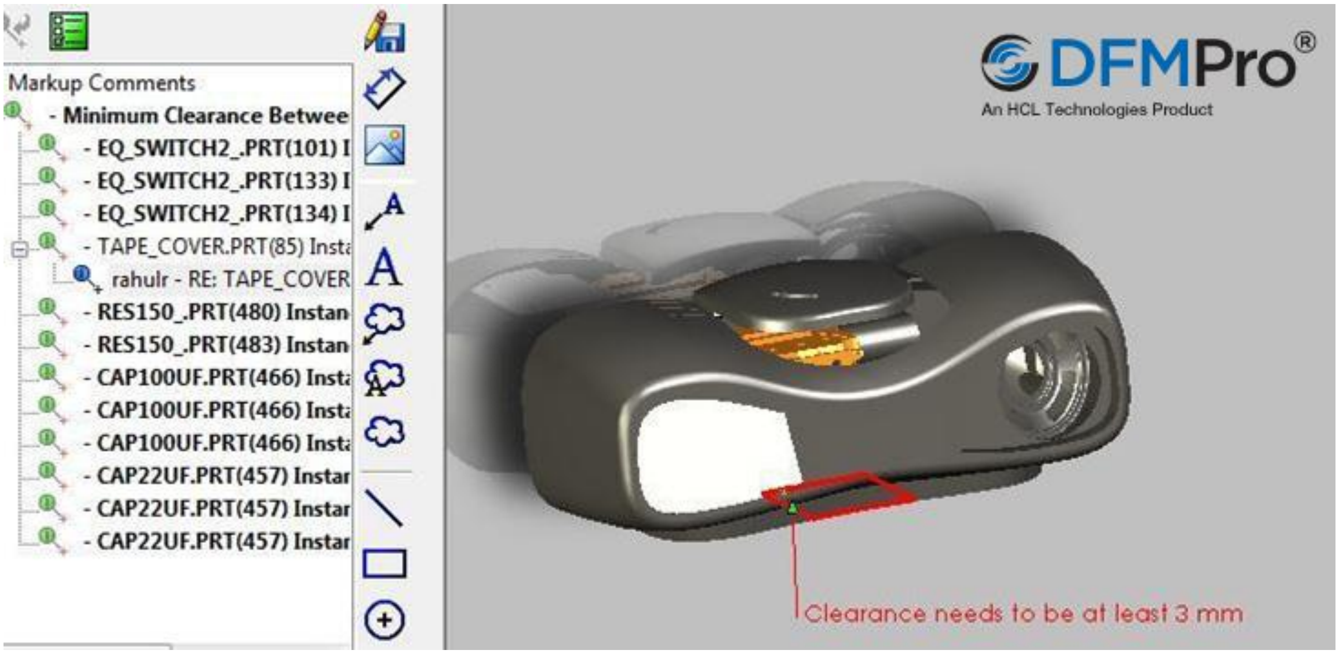


Figure 8: 3D report from DFMPro showing a clearance violation

Benefits

The requirements detailed above are just a few examples of the problems tackled by engineers when working with assemblies. By adopting specialized assembly level tools and checks early in the design process, organizations can avoid rework, scrap and late fixes when designs are being released to manufacturing or assembly, or in the worst case, have already been shipped. Rule- based assembly checks and utilities can save designers hundreds of hours in repetitive tasks and rework. A rule-based process, which is linked to the CAD environment, ensures that the documented standard and guidelines are embedded in software, reusable, easy to update and form part of the design cycle.

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